DOCUMENT RESUME

ED 241 307 SE 044 000

TITLE	Ocean Engineering Teaching at the University Level. Recommended Guidelines from the Unesco/IOC/ECOR Workshop on Advanced University Curricula in Ocean Engineering and Related Fields (Paris, France, October, 1982). Unesco Reports in Marine Science, No. 25.
INSTITUTION	United Nations Educational, Scientific, and Cultural Organization, Paris (France). Div. of Marine Sciences.
PUB DATE	83
NOTE	57p.
AVAILABLE FROM	Requests for copies should be on letterhead stationery, if possible, and sent to: Marine Information Centre, Div. of Marine Sciences, Unesco, 7 place de Fontenoy, 75700 Paris, France.
PUB TYPE	Collected Works - Conference Proceedings (021) -- Guides - General (050) -- Reports - Descriptive (141)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Audiovisual Aids; College Curriculum; *Curriculum Design; *Curriculum Development; Developing Nations; Educational Facilities; *Engineering Education; Environmental Education; *Fisheries; Higher Education; Human Resources; *Instrumentation; Marine Biology; *Ocean Engineering
IDENTIFIERS	*Engineering Curriculum

ABSTRACT

This report contains recommendations on advanced university curricula in ocean engineering and related areas, emphasizing the needs of developing countries. A decision matrix is included to assist users in developing the necessary criteria for designing appropriate curricula to prepare university students for careers in different ocean engineering fields. Examples of curricula in four fields are presented to illustrate use of the matrix. They include: (1) offshore structural engineering; (2) coastal and nearshore engineering; (3) ocean instrumentation; and (4) fisheries engineering. Discussions on necessary and desirable requirements for introducing advanced ocean engineering curricula in terms of human resources, physical facilities, and teaching aids are also presented. In addition, recommendations for the strengthening of ocean engineering in general are provided. (Author/JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED241307

SE

Unesco reports
in marine science

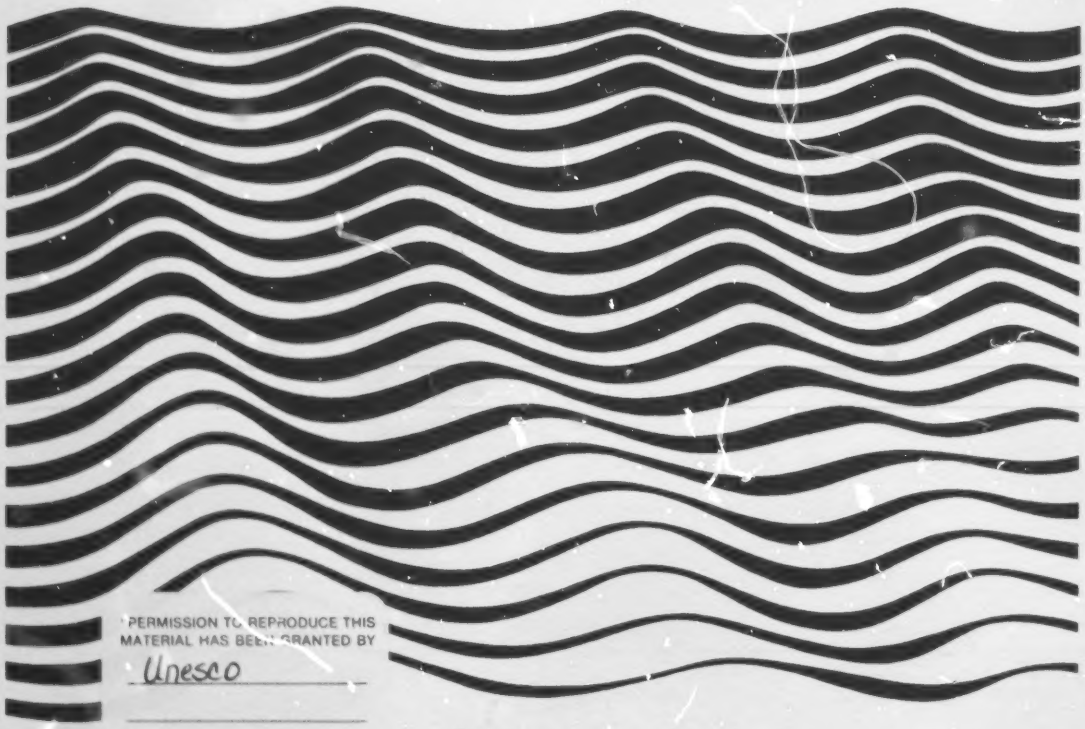
25

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)
✓ This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

Ocean engineering teaching at the university level

Recommended guidelines from the Unesco/IOC/ECOR workshop on advanced university curricula in ocean engineering and related fields

Paris, October 1982



SE 044000

PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Unesco

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Unesco, 1983

2

UNESCO REPORTS IN MARINE SCIENCE

No.		Year
1	Marine ecosystem modelling in the Eastern Mediterranean Report of a Unesco workshop held in Alexandria, Egypt, December 1974 English only	1977
2	Marine ecosystem modelling in the Mediterranean Report of the Second Unesco Workshop on Marine Ecosystem Modelling English only	1977
3	Benthic ecology and sedimentation of the south Atlantic continental platform Report of the seminar organized by Unesco in Montevideo, Uruguay, 9-12 May 1978 Available in English and Spanish	1979
4	Syllabus for training marine technicians Report of an IOC/Unesco workshop held in Miami, Florida, 22-26 May 1978 Available in English, French, Russian and Spanish	1979
5	Marine science syllabus for secondary schools Report of an IOC workshop held at United World College of the Atlantic, United Kingdom, 5-9 June 1978 Available in Arabic, English, French, Russian and Spanish	1979
6	Organization of marine biological reference collections in the Mediterranean Arab countries Expert meeting held in Tunis, 20-23 September 1978 Available in Arabic, English and French	1979
7	Coastal ecosystems of the southern Mediterranean: lagoons, deltas and salt marshes Report of a meeting of experts, Tunis, 25-27 September 1978 Available in Arabic, English and French	1979
8	The mangrove ecosystem: Human uses and management implications Report of a Unesco regional seminar held in Dacca, Bangladesh, December 1978 English only	1979
9	The mangrove ecosystem: scientific aspects and human impact Report of the seminar organized by Unesco at Cali, Colombia, 27 November-1 December 1978 Available in English and Spanish	1979
10	Development of marine science and technology in Africa Working Group of Experts sponsored by ECA and Unesco, Addis Ababa, 5-9 May 1980 Available in English and French	1980
11	Programa de Plancton para el Pacífico Oriental Informe final del Seminario-Taller realizado en el Instituto del Mar del Perú, El Callao, Perú, 8-11 de septiembre de 1980 Spanish only	1981
12	Geología y geoquímica del margen continental del Atlántico Sudoccidental Informe final del Taller de Trabajo organizado por la Unesco en Montevideo, Uruguay, 2-4 de diciembre de 1980 Spanish only	1981
13	Seminario Latinoamericano sobre Enseñanza de la Oceanografía Informe final del Seminario organizado por la Unesco en São Paulo, Brasil, 17-20 de noviembre de 1978 Spanish only	1981
14	Marine science and technology in Africa: present state and future development Synthesis of Unesco/ECA survey missions to African coastal states, 1980 Available in English and French	1981
15	Fishery science teaching at the university level Report of a Unesco/FAO workshop on university curricula in fishery science, Paris, May 1980 Available in Arabic, English, French, Russian and Spanish	1981
16	Marine and coastal processes in the Pacific: ecological aspects of coastal zone management Report of a Unesco seminar held at Motupore Island Research Centre, University of Papua New Guinea, 14-17 July 1980 English only	1981
17	The coastal ecosystems of West Africa: coastal lagoons, estuaries and mangroves workshop report, Dakar, 11-15 June 1979 Available in English and French	1981
18	Coral reef management in Asia and the Pacific: some research and training priorities Report of a Unesco workshop held in Manila, Philippines 21-22 May 1981 English only	1982
19	Mareas rojas en el Plancton del Pacífico Oriental Informe del Segundo Taller del Programa de Plancton del Pacífico Oriental, Instituto del Mar, Callao, Perú 19-20 de noviembre de 1981 Spanish only	1982
20	Quantitative analysis and simulation of Mediterranean coastal ecosystems: The Gulf of Naples, a case study Report of a workshop on ecosystem modelling Ischia, Naples, Italy, 28 March to 10 April 1981 Organized by the United Nations, Educational, Scientific and Cultural Organization (Unesco) and the Stazione Zoologica, Naples English only	1983
21	Comparison of coral reef survey methods A regional Unesco/UNEP workshop, Phuket Marine Biological Centre, Thailand, December 1982 English only	1983
22	Guidelines for marine biological reference collections Prepared in response to a recommendation by a meeting of experts from the Mediterranean Arab countries Available in English, French and Arabic	1983
23	Coral reefs, seagrass beds and mangroves: their interaction in the coastal zones of the Caribbean Report of a workshop held at West Indies Laboratory, St. Croix, U.S. Virgin Islands, May, 1982 English only	1983
24	Coastal ecosystems of Latin America and the Caribbean The objectives, priorities and activities of Unesco's COMAR project for the Latin America and Caribbean region - Caracas, Venezuela, 15-19 November 1982 Available in English and Spanish	1983

Unesco reports
in marine science 25

Ocean engineering teaching at the university level

Recommended guidelines
from the Unesco/IOC/ECOR workshop
on advanced university
curricula in ocean engineering
and related fields

Paris, October 1982

Unesco, 1983

Published in 1983 by the United Nations Educational,
Scientific and Cultural Organization
7, place de Fontenoy - 75700 Paris

Printed in Unesco's workshops.

© Unesco 1983
Printed in fra[illegible]

Reproduction authorized, providing that appropriate
mention is made of *Unesco reports in marine science*
and voucher copies are sent to the Division
of Marine Sciences.

PREFACE

Unesco Reports in Marine Science are designed to serve specific programme needs and to report on developments in projects conducted by the Unesco Division of Marine Sciences, including those involving collaboration between the Division and the Intergovernmental Oceanographic Commission, particularly in the field of training, education, and mutual assistance in the marine sciences.

Designed to serve as a complement to the Unesco Technical Papers in Marine Science, the Reports are distributed automatically to various institutions and governmental authorities. Individuals may, at their request, receive copies of specific titles, but cannot be included on the automatic distribution list. Both the Reports and the Technical Papers series are free of charge.

Requests for copies of specific titles or for additions of institutions or authorities to the mailing list should be addressed, on letterhead stationery if possible to:

Marine Information Centre
Division of Marine Sciences
Unesco
Place de Fontenoy
75700 Paris
France.

ABSTRACT

This report contains recommendations on advanced university curricula in ocean engineering and related fields. The report was prepared by an international workshop which was held at Unesco, Paris, from 11 to 16 October 1982. The report presents a decision matrix to assist users in developing the necessary criteria for designing appropriate curricula to prepare university students for careers in different ocean engineering fields. Example curricula in the following four fields are presented, illustrating the use of the matrix: offshore structural engineering, coastal and nearshore engineering, ocean instrumentation, fisheries engineering. The report includes discussions on necessary and desirable requirements for introducing advanced ocean engineering curricula in terms of human resources, physical facilities and teaching aids. It further gives recommendations for the strengthening of ocean engineering education in general. This workshop was the fifth in a series of Unesco-sponsored workshops aimed at providing guidelines for the establishment or reinforcement of teaching and training in marine related fields at different educational levels.

TABLE OF CONTENTS

	Page
INTRODUCTION	5
Background	5
Ocean Engineering	8
WORKSHOP RECOMMENDATIONS	11
DECISION ANALYSIS IN CURRICULA DESIGN	13
Problem Definition	13
National Requirements for Ocean Engineers	13
Designing the Curriculum	14
A Decision Matrix for Curricula Design	15
Organization of the Curriculum	23
EXAMPLE OCEAN ENGINEERING CURRICULA	25
Introduction	25
Common Features of the Example Curricula	25
Example Curricula	26
A. Offshore structural engineering	26
B. Coastal and nearshore engineering	29
C. Ocean instrumentation	32
D. Fisheries engineering	35
TEACHING RESOURCES AND FACILITIES	38
Introduction	38
Human Resources	38
Physical Facilities	39
Teaching Aids	42
ANNEXES	
I. List of Workshop Participants	43
II. Programme Accreditation and Professional Licensing	46
III. Publications Useful for the Design of Curricula	47
IV. Bibliographies and Selected Publications	49

INTRODUCTION

Background

The purpose of this report is to provide guidance in the design of curricula in the field of ocean engineering at the advanced university level. The report includes criteria for the design of postgraduate ocean engineering curricula, presents example curricula, comments on teaching facilities and resources and provides recommendations to the workshop's sponsoring organizations, university administrators and others.

In this report, the main emphasis is on the development of ocean engineering educational programmes (and their associated resources) at the level of the master's degree or equivalent. Such programmes might follow a three or four year bachelor's degree course (in countries where this system operates), or form an optional programme in the final two years of a five or six year course, such as is offered, for example, in some European countries and Argentina. Courses at this level are likely to be the principal means whereby ocean engineering education is introduced into university work during the near future; however, in the longer term, there is likely to be an extension of ocean engineering educational activity both upwards to the doctoral level and downwards into the undergraduate level. The recommendations of this report are applicable to institutions in both developing and in developed countries, which desire to develop training in ocean engineering.

The word 'university' has been used in the report as a convenient way of referring to any educational institution that either provides recognized teaching programmes in engineering at the postgraduate level, or intends to become capable of offering programmes of study at this level. The word 'university' thus includes those polytechnics, institutes of technology, etc. that satisfy the foregoing criteria. 'Curriculum' is defined as the organized set of knowledge, skills and attitudes to be imparted to students, and the educational activities to achieve this goal.

The Working Committee on Training, Education and Mutual Assistance (TEMA) of the Intergovernmental Oceanographic Commission (IOC) in its second meeting, held in New York in 1977, formally asked the Unesco Division of Marine Sciences to explore how TEMA-related ocean engineering activities could most effectively be organized and made available to IOC member states. It was decided that the initial major effort by Unesco, in collaboration with the Engineering Committee on Oceanic Resources (ECOR), a non-governmental organization, should be directed towards the development of university curricula in ocean engineering so as to provide advice to those countries and institutions initiating training in this field. Two outputs of the

project were foreseen: (1) a global survey of the ocean engineering curricula of universities and institutions that already provide such education, and (2) advice on designing ocean engineering curricula prepared by eminent university professors and teachers, based on their own experience and on the results of the global survey, through a workshop.

The global survey was carried out by Dr. Adrian F. Richards, who also co-operated in preparing the workshop. In order further to present the views of the international ocean engineering community, the draft results of the global survey were circulated to about forty ocean engineers in academic and governmental institutions and industry to obtain additional comments and critique. The results of the survey are published in Unesco Reports in Marine Science No. 25, Global Survey and Analysis of Postgraduate University Curricula in Ocean Engineering by A. F. Richards and E. A. Richards. That report complements, and should be used in conjunction with, the present report. The global survey indicated that ocean engineering curricula exist in nearly 100 universities representing 19 countries. It further showed that there is a reasonable commonality of programmes.

The present report gives the results of the Workshop on Advanced University Curricula in Ocean Engineering and Related Fields held at Unesco Headquarters in Paris from 11 to 16 October 1982. Fourteen widely experienced professors and teachers of diverse specialities in ocean engineering from eleven countries participated in the workshop (see Annex I). The workshop was sponsored by the Unesco Division of Marine Sciences and Division of Technological Education and Research, by the Intergovernmental Oceanographic Commission of Unesco, and the Engineering Committee on Oceanic Resources.

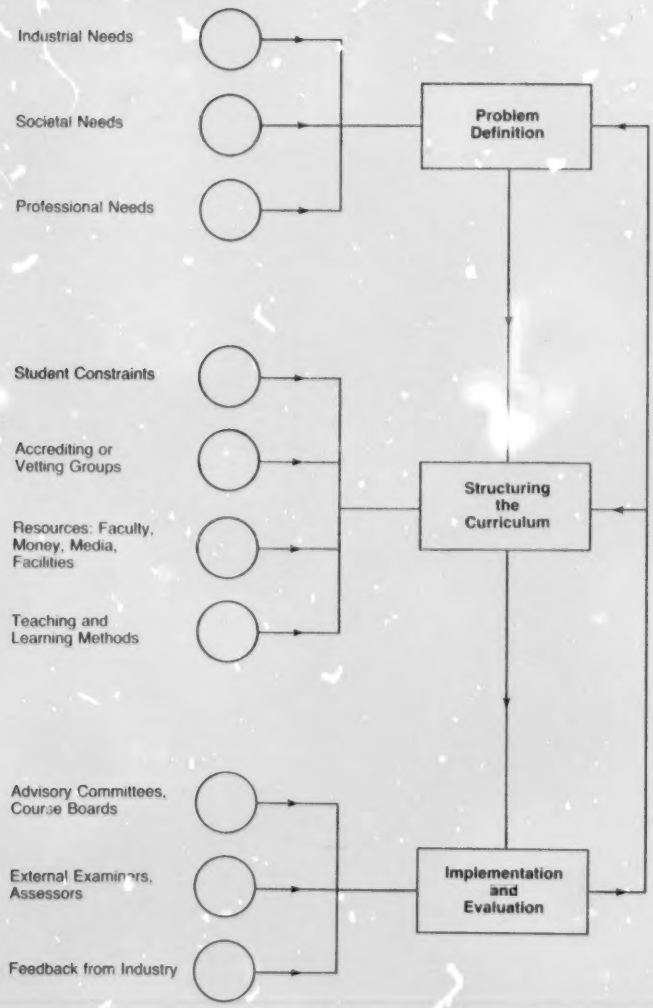
The objectives of the workshop were: (1) to develop guidelines for designing curricula in ocean engineering, (2) to design example curricula for ocean engineering specializations that were to be identified, (3) to recommend prerequisites for entering the various curricula, and (4) to identify required human resources and facilities. The needs of developing countries particularly were to be taken into account. During the course of the workshop it was also found necessary to develop a common understanding on the content of the field of ocean engineering.

Grayson* presented a three-part methodology (Fig. 1), which specifies important stages in the design of a curriculum. While all of the parts are directly pertinent to this report, emphasis is placed on Grayson's 'Problem Definition'. The next two substantial chapters address this subject, first by providing a means of decision-making taking into account industrial, societal and professional needs, and second by showing several examples. The final chapter considers Grayson's 'Structuring the Curriculum' by citing some selected resources. Comments on the accrediting or vetting process are given in Annex II.

---

* Grayson, L. P., 1977. The design of engineering curricula, Unesco studies in engineering education 5. Unesco, Paris.

Figure 1. General stages in a methodology for curriculum design (Grayson, 1977)



Neither student constraints nor teaching and learning methods are addressed, because these important considerations tend to be rather unique to each university. Time did not permit Grayson's part on 'Implementation and Evaluation' to be discussed in the workshop. This is an area that frequently is given inadequate attention in curriculum development by university faculty or administrators. It deserves very careful consideration to maximize the usefulness of the curriculum to the original industrial, societal and professional needs.

The extensive work of Dr. Adrian F. Richards, originally Professor of Oceanography and Ocean Engineering at Lehigh University, U.S.A., and subsequently Vice President for Research and Development at Fugro B.V., the Netherlands, in carrying out the global survey and collaborating in preparing the workshop and in editing the workshop report is especially acknowledged. This report would not be possible without the fine efforts of the participants of the workshop. The matrix analysis by Professor Foster H. Middleton is appreciated.

Ocean Engineering

'Ocean Engineering' in the broadest interpretation, covers the technological activities associated with the exploration and the use of the sea, including the marine atmosphere, sea coast, sea bed and the sediments and rocks beneath the sea. In principle, this field encompasses activities such as marine petroleum and gas technology (drilling, production and distribution), subsea mining, shipping, recreation, fishing technology, etc. However, in the present context of curricula development, this workshop emphasizes those aspects of ocean engineering related to activities of design, fabrication and operation of ocean structures (vessels, vehicles, platforms, pipelines and outfalls, harbours, etc.); to the design and use of equipment for power supply, computing, telecommunications and positioning, as well as for control of offshore operations such as diving, data acquisition and processing; to the broad aspects of marine safety; and to the planning of systems for transportation, pollution control and coastal protection, together with the related aspects of marine affairs. Examples of a number of ocean engineering subfields often used in academic curricula are listed in Table 1.

Ocean engineering is particularly dependent upon, and closely interacts with, the various fields of marine science. Thus the engineer provides support in connection with the development of instruments and vessels for exploration and survey. In turn, the ocean engineer almost always receives input from the marine scientist about physical, geological, chemical and biological oceanographic conditions.

Effective future global development depends upon adequate knowledge and skills to plan and manage this development. The resources of the sea and related technological

activities represent an important opportunity for social and economic development, and hence a challenge. Such activities, on the other hand, require careful management to maintain the safety of human lives and property, and to maintain a balanced environment. An understanding of the sociological impact of technological development is needed, particularly by countries developing industrial activities, to ensure the sustainable productivity of the environment. Political considerations with regard to ocean engineering might include national management of the utilization of ocean resources, as well as employment policies.

Table 1. Examples of ocean engineering subfields

Dredging
Fisheries engineering
Harbour and coastal engineering*
Marine engineering*
Mining engineering
Offshore engineering*
Naval architecture*
Underwater acoustics
Water quality of estuaries engineering

* Subfield name used in 'Global survey and analysis of postgraduate university curricula in ocean engineering', Unesco reports in marine science 26.

An expansion of ocean activities, especially in industralizing nations is expected in the years to come. The safe and effective development of ocean resources implies a significant demand for people who are appropriately trained and educated. The number of qualified people required will likely be influenced by national policies and circumstances.

The basic objectives of a university education in ocean engineering are to prepare for work relating to: (1) technology and engineering science (problem solving and design), (2) management of technological activities, and (3) interaction between technology and society. This work may be carried out in government agencies, consulting companies, research and development organizations or teaching establishments.

Engineering is both multidisciplinary (involving several basic sciences, such as mathematics, natural sciences and various engineering disciplines) and interdisciplinary. Therefore, ocean engineers should be highly qualified in at least one specialization and have a basic knowledge of several others. Educational priorities will depend upon the needs of a particular country or region.

WORKSHOP RECOMMENDATIONS

The workshop participants unanimously adopted a number of recommendations. The preamble that follows represents a summary of some of the points the participants considered to be particularly relevant. The first set of recommendations are applicable to any governmental organization, university, or individual concerned with establishing or assisting in the establishment of any ocean engineering curricula. The second set is specifically directed to Unesco and its IOC, for action in co-operation with other United Nations agencies, organizations and committees, and Member States.

The Unesco/IOC/ECOR Workshop on Advanced University Curricula in Ocean Engineering and Related Fields:

Recognizing that:

(a) Ocean engineering is a very broad area and one single programme cannot cover all aspects;

(b) In preparing plans for the development of an ocean engineering programme:

(i) the national needs for ocean engineering must first be identified;

(ii) the educational objectives of an ocean engineering curriculum must be clearly defined in relation to those societal needs;

(iii) the output of students from ocean engineering educational programmes should be matched as closely as possible with present and future manpower requirements for qualified ocean engineers;

(c) The choice of a particular specialization for the programme essentially depends on the perceived needs and the available expertise;

(d) There should be a high-quality core of faculty forming a critical nucleus before an ocean engineering postgraduate programme is attempted;

(e) Good undergraduate programmes in traditional engineering disciplines are prerequisites for starting a postgraduate programme in ocean engineering;

(f) Development and implementation of ocean engineering educational programmes are expensive and therefore these should be attempted only if adequate funds are available.

Recommends to all concerned :

(a) To involve research, design and field engineers in the development of ocean engineering educational programmes;

(b) To give high priority to the organization of intensive training programmes for ocean engineering teachers, including summer schools;

(c) To give incentives to attract good students to ocean engineering graduate programmes;

(d) To support educational institutions in conducting research, and to promote close interaction between universities and research institutions;

(e) To provide for practical experience dealing with the marine environment for ocean engineering students;

(f) To offer an ocean engineering course to undergraduate students in the traditional engineering disciplines to introduce them to the aspects and challenges of ocean engineering;

(g) To promote the preparation of lists of textbooks and other teaching aids in appropriate languages for use in the education of ocean engineering students.

Further recommends that Unesco and its IOC take steps to encourage the following, in co-operation with other U.N. organizations, non-governmental organizations, such as ECOR, and Member States:

(a) To give due importance to ocean engineering and to take steps similar to those that have been taken or are planned for the strengthening of marine sciences;

(b) To assist in making available ocean engineering expertise and equipment to countries developing educational programmes in this area;

(c) To convene regional workshops on ocean engineering education and curricula development as a follow-up to the present workshop;

(d) To provide practical experience in dealing with the marine environment for ocean engineering students;

(e) To provide fellowships and travel and study grants for teachers and students, in order for them to become acquainted with the activities of, or to study at, well-established ocean engineering institutions;

(f) To support national and regional ocean engineering programmes, or to strengthen existing ones, and to fund them adequately.

DECISION ANALYSIS IN CURRICULA DESIGN

Problem Definition

Those problems and questions that must be decided to develop a significant ocean engineering programme within a university are addressed in this chapter. Probably the three most important questions should be: (1) what requirements of ocean engineering manpower exist in the country or region, (2) what should be the design of appropriate curricula to meet this need, and (3) how should the organization of an ocean engineering programme be made? These matters will subsequently be discussed.

National Requirements for Ocean Engineers

A prerequisite to establish a university curriculum in ocean engineering is to identify those needs of society that are to be satisfied by that curriculum. Broadly, these needs are two-fold: (1) to supply the trained manpower necessary to service the ocean engineering activities within a nation or region, and (2) to increase and improve the physical facilities needed for ocean engineering developments. Since this chapter is concerned with curriculum development, only the second of the above needs is considered below.

It follows that some fundamental questions need to be answered before designing an ocean engineering curriculum:
What ocean engineering activities are to be developed?
How many engineers will be required?
What levels of education and training will they need to have?
Should the necessary manpower and expertise be sought from other countries?
Should engineers be trained and/or educated in the country concerned, or abroad?

The answers to all of these questions depend on national circumstances and therefore, no general answers are put forward in this report. It is noted, however, that these basic questions are not always properly confronted, and that considerations of prestige or fashion can sometimes adversely influence decisions affecting the curriculum. Some points for guidance are mentioned below.

Firstly, it is suggested that some attempt should be made to predict the future requirements for trained manpower. Surveys among prospective employing organizations can help to identify both the numbers of personnel required and their necessary levels of qualification. It should be noted that for every required professional engineer (i.e. with a postgraduate-level or equivalent qualification) usually there will also be a requirement for a larger number of supporting staff (e.g. technicians). There must therefore be

appropriate provisions for the training and education of these supporting staff. This important matter is not considered further in this report, which is concerned primarily with graduate-level engineers.

Secondly, the decision as to whether to develop an ocean engineering curriculum must be strongly influenced by the projections of manpower demand. If the required numbers are small, possibly fewer than 10 per annum, it may be more cost-effective to have these engineers educated in ocean engineering at institutions abroad. (It may even be more efficient, at least intially, to obtain the necessary manpower and expertise in ocean engineering from overseas). It can be very detrimental to the long-term health of a university venture in ocean engineering to produce large numbers of graduates or specialists for whom employment does not exist.

Thirdly, it is recommended that universities in countries undergoing industrialization should not model prospective curricula on those in the universities of fully industrialized countries. It is very important to develop an ocean engineering curriculum to fit as closely as possible national or regional needs rather than the perceived needs in other countries.

Designing the Curriculum

After having addressed the questions posed above, and having made a decision to develop an ocean engineering curriculum in a particular university, there remains the question of how can this best be done?

It was the concensus of the workshop participants that there is no unique nor ideal approach to the establishment of an ocean engineering programme or department. The reason for this conclusion is that every situation must be evaluated in relation to existing engineering programmes and facilities. It is recommended that moving into ocean engineering at the postgraduate level should only be attempted where strong conventional engineering programmes exist together with the usual supporting mathematics and physics.

It is likewise clear that ocean engineering is very much an interdisciplinary field, and there are a number of recognized specialties within it. Incoming students should certainly possess engineering expertise that might have been acquired through a Bachelor of Science degree, or through the first three or four years of a longer diploma programme. In the event that an incoming student does not possess this background in engineering, but rather has graduated in mathematics, physics, geology, or a physical science, he or she should be required to take appropriate engineering courses on an individual basis.

There are some academic subjects or courses that are of common interest to all ocean engineering students. These might be called 'core' subjects and some latitude in selecting these courses may be provided to the student in the formation of his or her course of study. The core subjects may include ocean science courses. None of the core subjects are intended to produce specialists in that subject. Instead, it is intended that they provide all students with an introduction to ocean processes and thus to develop an appreciation of how conventional engineering subjects relate to the ocean. The balance of a particular curriculum for each student will depend upon the ocean engineering subfield that is elected, and it should include courses and subjects drawn from a rather large list of electives, most of which would be more technically advanced than the core subjects.

A Decision Matrix for Curricula Design

To assist in the process of deciding the appropriate constituents of an ocean engineering curriculum, a matrix of the kind shown in Fig. 2 may be helpful. Each university will need first to identify the broad objectives and scope of its ocean engineering education, which will depend on national priorities and needs, and will be influenced by available resources, other educational activity in the country, etc. Within these broadly defined objectives, it will then be necessary to specify the educational goals of the particular curriculum to be designed. These may relate to: (1) a rather specific type of ocean engineering activity, such as hydrocarbon recovery, transportation or coastal development, or (2) introducing students to a wider range of ocean engineering subjects by providing a broader, less specialized curriculum. In either case, once the educational objectives of the curriculum have been defined, it will be necessary to identify the appropriate subjects of study, or courses, in that curriculum, and to assign some priority, or weighting, to each of them. A matrix (Fig. 2) has been prepared to assist in this process.

The rows of the matrix represent the primary activities or uses of the sea, which together constitute ocean engineering according to the broad definition adopted in the first chapter. The columns of the matrix are subjects of study. In its original scheme, the workshop participants attempted to define these simply in terms of the major disciplines of engineering - mechanical, civil, etc.; however, this was found to be inadequate for two reasons. Firstly, such definitions were too imprecise. Secondly, a subject such as hydromechanics might appropriately be taught by a civil engineer, a mechanical engineer or a naval architect, and should not therefore be represented in the matrix as part of one particular discipline. This difficulty was alleviated by the method finally selected.

Tables 2 and 3 provide brief explanations of the individual headings in the horizontal rows and vertical columns, respectively, of the matrix (Fig. 2). Space is provided under each of four major academic disciplines in the matrix to add additional subjects.

A slightly abbreviated matrix was filled in individually by many, but not all, of the workshop participants, who were instructed to indicate the degree of correlation that existed between each ocean engineering activity and a particular academic discipline. The degree of correlation was reported by each respondent by inserting a number ranging from one to four in each box intersected by the row and column elements. The matrix contributions of all respondents were gathered and numerically totaled for each matrix element, after discarding the distorted individual contributions resulting from leaving a matrix element blank. This summary matrix (Fig. 3) was produced by establishing a scale ranging from white to black for each matrix element. The degree that each square is filled in with black is proportional to the perceived amount of correlation between each activity and each academic discipline. It is to be noted that the variance in the contributions by the respondents was generally larger than expected. This is most likely due to the diverse backgrounds of the respondents.

The correlations shown must not be taken literally for two reasons. Firstly, the number of respondents was small. Secondly, neither the four major nor the twenty-four minor academic disciplines or subjects correspond uniformly to ocean engineering subjects discussed in this report or elsewhere.

An institution with an interest in establishing an ocean engineering programme or department hopefully might find the matrix of some use. A new programme will logically start small, and address specific activities that are of immediate concern to the institution. By entering the matrix on the corresponding academic discipline, the greater proportion of black for each matrix element will then indicate in a crude way those subjects or disciplines that correlate highly to a specific activity. An assemly of subjects, or courses, may thus be formulated into a curriculum from the elements having the highest correlation measures, in a rough order of priority. This is the final stage of the decision process: to select those subjects of study that are necessary or desirable to meet the educational objectives of the institution.

University faculties are strongly encouraged to modify and expand the matrix presented in this report in whatever way they believe appropriate to maximize its usefulness. Examples of specific ocean engineering curricula are given in the next chapter. Annex III provides the names of several publications that may be useful in designing ocean engineering curricula.

Figure 2. Ocean engineering decision analysis matrix

ACADEMIC DISCIPLINE

OCEAN ENGINEERING ACTIVITY		Marine Science					Structures & Materials								Instrumentation, Telecommunications & Equipment							Marine Systems' Operation & Management						
		Physical	Geological	Chemical	Biological & Ecological		Hydromechanics & Hydraulics	Load Action Analysis	Mechanics of Structures	Design of Structures	Materials	Geotechnology	Erosion & Deposition	Water Quality	Thermodynamics	Data Acquisition & Processing	Telecommunications	Positioning	Marine Power Systems	Machinery & Tools	Controls	Computers	System Design & Development	Human Aspects	Offshore Operations	Construction & Installation	Marine Affairs	Safety	
Marine Resources Development	Hydrocarbons																											
	Minerals																											
	Bio-Resources																											
	Energy																											
	Water																											
Trans-portation	Ships & Vehicles																											
	Cables																											
	Pipelines																											
Explor. & Survey	Data Acquisition & Analysis																											
	Scientific Exploration																											
Environmental Protection	Pollution Control																											
	Erosion & Siltation Control																											
	Controlled Waste Disposal																											
	Security																											
Coastal & Nearshore Development	Ports & Harbours																											
	Plants, Terminals & Storage																											
	Recreation & Habitation																											
	Reclamation																											

Table 2. Explanation of the ocean engineering activities of the matrix

Marine Resource Development

This subject refers to the technical and engineering work involved in extracting or utilizing the various resources in and beneath the sea:

Hydrocarbons
especially oil and gas

Minerals
(including sand and gravel), on or in the seabed in mineral-rich deposits (phosphorites, polymetallic nodules and sulfides, etc.)

Bio-resources
especially fish and shellfish, but also other marine organisms, algae, etc.

Energy
including tidal, current, wave, thermal and salinity gradients, biomass (e.g. kelp conversion), marine applications of solar or wind energy

Water
including desalination processes, use of icebergs, etc.

Transportation

Commodities, people, materials, power, etc. and how they may be transported on, or in, the sea and on the seabed. The major modes are:

Ships and Vehicles
including barges, semi-submersibles, submersibles, hovercraft, hydrofoils, etc.

Cables
for electrical energy transmission and communication

Pipelines
especially for oil and gas, but possibly for slurries, chemicals, etc.

Exploration and Survey

The extension of man's knowledge of the sea has two main aspects:

Data Acquisition and Analysis
(including display) covering hydrographic work, oceanography, tidal data, and the associated preparation of charts and tables

Table 2 continued

Scientific Exploration
to discover more about the resources, constituents, phenomena and behaviour of the oceans and seabed

Environmental Protection

Man's activities intended to prevent damage, deterioration or loss affecting the sea, its margins and the associated man-made systems:

Pollution Control
including effluents or discharges from land, ships, offshore systems or operations

Erosion and Siltation Control
coastal protection and dredging

Controlled Waste Disposal
planned use of the sea as a sink for waste materials, heat, sound, etc.

Security
protection of assets from hazards, both accidental and deliberate

Coastal and Nearshore Development

Activities to enhance, utilize or develop coasts and coastal waters:

Ports and Harbours

Industrial Plants, Terminals and Storage
(including bridges) floating or bottom-based installations for industrial or operational purposes (e.g. airports)

Recreation and Habitation
ranging from yachting marinas and leisure amenities to artificial islands

Reclamation
of land from the sea.

Table 3. Explanation of the academic disciplines of the matrix

Marine Science

Physical
waves, currents, winds, temperatures, ice, tides, storm surges, internal waves, tsunamis

Geological
geomorphology, sedimentology (sediment sources and ages, processes), coastal processes, heatflow, tectonics, earthquakes, volcanoes, underwater slumps and slides

Chemical
composition of seawater and brines, geochemical processes

Biological and Ecological
fish, food chain, fouling, borers, algae, bacteria

Structures and Materials

Hydromechanics and Hydraulics
loading, mixing and trajectories, coastal wave refraction and diffraction, shoaling, currents, tidal hydraulics, storm surges; hydrodynamics (including stability) of vehicles and structures

Load Action Analysis
identification and quantification of all significant functional, environmental and accidental loads

Mechanics of Structures
structures: floating, fixed offshore, coastal; pipelines; moorings: tethered, articulated; motion response (rigid and flexible bodies)

Design of Structures
(including physical and numerical modeling)

Materials
strength, fatigue, corrosion, fouling, abrasion

Geotechnology
foundations, soil mechanics, behaviour of soils, sea-floor improvement, fixed soils, sub-sea slumping and slides, stability

Erosion and Deposition
movement of seabed materials, accretion

Water Quality

Table 3 continued

Thermodynamics
thermal energy extraction (vertical gradients of temperature), desalination processes, reverse osmosis, etc.

Instrumentation, Telecommunication and Equipment

Data Acquisition and Processing
measurement equipment, remote sensing, data processing

Telecommunication
wire, microwave, radio/acoustic/optics - including underwater TV

Positioning
(including dredging and production equipment), platforms, pipelines, vessels and vehicles

Marine Power Systems

Machinery and Tools

Controls
pipeline, tensioning, ballasting, ship positioning, drill-hole re-entry, etc.

Computers
dedicated computers to onboard computing functions

Marine Systems' Operation and Management

System Design and Development
planning and design of total systems (including evacuation and rescue systems)

Human Aspects
diving, life support, operators of ships, barges, etc.

Offshore Operations
inspection, integrity, monitoring, maintenance, operations in general

Construction and Installation
management of design construction, installation and operations

Marine Affairs
legal, social, political; regulations, conventions and codes of practice

Safety
environmental protection, human safety, risk analysis.

Figure 3. Ocean engineering decision analysis matrix completed by workshop

Organization of the Curriculum

There are two broad approaches to the way in which an ocean engineering curriculum may be organized. The question to be resolved is : (1) should there be a separate Department of Ocean Engineering, or (2) should ocean engineering be introduced as a supplementary curriculum in one or more existing departments? Although the answer will, of course, be strongly influenced by local circumstances, some advantages and disadvantages of creating a separate ocean engineering department are listed below.

Advantages:

1. There will be a clear commitment to, and responsibility for, the ocean engineering programme;

2. Undivided attention can be given to the creation of the elaborate facilities that may be required;

3. There will be a distinct, specific budget, and additional funds may be more readily obtained from industry and/or organizations;

4. Decision-making and implementation of ocean engineering programmes will be facilitated;

5. Collaboration in multi-departmental programmes may be made easier and more congenial.

Disadvantages:

1. There may be some duplication of facilities;

2. Access to existing facilities in other departments may be restricted;

3. The expertise in other departments may not be so readily available;

4. In its early years, the new ocean engineering department may be weak in comparison with existing departments.

It is recommended that special arrangements should be made for ocean engineering teaching. This may be either through co-operation between existing departments, or through the creation of a separate ocean engineering department. If local circumstances favour the 'separate concept', the following guidelines are suggested:

1. The organization should be similar to and with the same authority (within the university) as a department, but perhaps with a different name (centre, school, etc.);

2. The ocean engineering entity should not duplicate the facilities already available and should only create additional facilities (which in most cases will also be useful for activities in the traditional departments);

3. Through this entity should be encouraged the concept of joint appointments from among the faculty and staff, in addition to the core ocean engineering faculty and staff;

4. A standing committee should be established for the ocean engineering entity, which represents all participating departments for better coordination and exchange of facilities and expertise.

Once the major elements of an ocean engineering curriculum have been designed and organized, the next task will be to formulate detailed curricula, examples of which are given in the next chapter.

EXAMPLE OCEAN ENGINEERING CURRICULA

Introduction

Specific curricula will need to be developed after personnel in an institution or a department have considered the general criteria of curricula identification given in the previous chapter. This chapter presents guidelines and a few example curricula to demonstrate the next step in the decision process. It is emphasized that the curricula presented are only illustrative examples and no priority is assigned.

Any engineering curriculum at the postgraduate or advanced level must also reflect the breadth and depth of technical and nontechnical training obtained prior to entering a specific curriculum. The length of the programme in terms of the number of lecture hours, subjects, etc., must also be considered. Some guidance in these matters is offered, but much must be decided locally on the basis of the existing institutional infrastructure, capabilities of the faculty, availability of instructional resources, etc.

Many subfields of ocean engineering were considered for possible preparation of sample curricula. It was concluded that the preparation of sample curricula was not necessary for some fields, such as naval architecture, in which many successful curricula are now well established. Further particulars regarding naval architecture and marine engineering curricula are presented for specific universities in the companion Unesco Reports in Marine Science 26.

Common Features of the Example Curricula

Details of the example curricula in four different aspects of ocean engineering are given in the following section. For each curriculum the following information is presented:

1. Objectives of the curriculum,
2. Core subjects with brief descriptions of each,
3. Elective subjects,
4. Project or thesis,
5. Additional information.

A prerequisite for all example curricula is that students should either have reached the bachelor's degree or equivalent level in the necessary engineering field including related subjects, or have attended suitable bridging courses. Some of the ocean engineering courses include mathematics, others do not. There are some differences in the level of mathematics achieved in first degree programmes, and particular attention may need to be given to this aspect of a student's preparation to enter the proposed ocean engineering courses.

The majority of master's-level curricula contain a range of elective subjects and many involve project work, leading to the submission of a thesis. However, the proportion of time a student spends on each of these three main activities varies considerably in different curricula. As a result, only an approximate time percentage for each subject in the four example curricula has been recommended. More precise time allocations can best be made based on local conditions.

Whether a semester, trimester or other academic system is in use, it is expected that in a two-year master's programme there would be a total of about 60 working weeks. In each week, about 15 hours would be spent in formal lectures. Hence, a student would receive a total of 900 hours of lectures, together with similar amounts of time scheduled for programmed study, including course, laboratory, practical or tutorial work and for private study.

Example Curricula

A. Offshore Structural Engineering

1. Objectives

This curriculum is designed to provide the student with the scientific and professional knowledge necessary in the field of offshore structural engineering. It will develop the student's abilities to formulate solutions to new and complex problems in the planning, design and construction of offshore structures. It will also provide an understanding of current economical, technical and environmental problems.

2. Core subjects

	Suggested Time Allocation per cent
Mathematics Topics from applied mathematics; probability theory; statistics.	10

	Suggested Time Allocation per cent
Physical and geological oceanography Air-sea interactions; wave statics and wave climate, including wave spectra; oceanic currents; internal waves; ice and icebergs; marine geology; plate tectonics and earthquakes; underwater slurps and slides.	6
Hydromechanics Potential and viscous flows, turbulence; theory of waves; wave deformation; wave-induced forces; theory of tides and currents.	6
Ocean structures and materials Description of ocean structures, drilling rigs, underwater mining equipment and dredges; hydrostatic characteristics and stability; corrosion control; marine fouling; fracture mechanics; fatigue.	6
Dynamics of ocean structures and floating bodies Analytical methods in vibration analysis; system parameters; structural response to steady and unsteady loading; derivation of equations of motion; motion response, both deterministic and random.	6
Advanced structural analysis Fundamentals of elasticity and plasticity; matrix methods; stability; use of finite element analysis techniques.	6
Marine geotechnical engineering Marine soil exploration methods; strength and deformation of soils, soil behaviour under dynamic loads; bearing capacity; settlements.	6
Design of offshore structures Overall systems design, including foundation analysis, construction and installation constraints; detailed design of space frame and tubular joints; stability and stresses during towing and sinking; risk analysis; verification of design in conformity with codes.	6
Construction of offshore structures Methods of construction and installation of steel jacket and concrete gravity structures; construction equipment; construction management; quality control, techniques of underwater concrete placement; submarine pipeline laying; economics; safety.	6
Subtotal	58

	Suggested Time Allocation per cent
3. Elective subjects	
Design of steel structures	6
Design of reinforced concrete structures	6
Wave mechanics	6
Marine foundations	6
Submarine pipelines and storage tanks	6
Sea surveying	6
Plated structures and shells	6
Navigation and positioning of offshore structures	6
Subtotal	24 *

* A minimum of four elective subjects are required, chosen in consultation with the student's advisor.

4. Project or thesis	
Independent study project with technical report or thesis	12
Oral examination on the above	6
Subtotal	18

5. Additional information	
Industrial experience is desirable.	
Curriculum total	100

B. Coastal and Nearshore Engineering

1. Objectives

This curriculum is designed to educate a student in the knowledge, techniques and skills necessary for coastal and nearshore engineering. The curriculum includes both the engineering development of coastal areas, and the protection of these areas against the undesirable environmental impact of such development.

2. Core subjects

	Suggested Time Allocation per cent
Physical oceanography and marine meteorology Introduction to air-sea interaction; exchange processes for momentum and heat; oceanic currents; internal waves; marine meteorology.	4
Geology and coastal morphology Introduction to geology, morphology; sedimentology; tectonics and earthquakes; underwater slumps and slides; mineralogy.	4
Wind waves and swell Linear and nonlinear wave theories; wave generation; wave forecasting and data collection; wave deformation and run-up; wave spectra; wave-current interaction.	6
Tides, seiches, tsunamis and currents Tide generation; tide level; tidal currents; seiches and surf beat; tsunamis; oceanic currents; wave setup and nearshore currents; density currents.	6
Water quality Mixing processes; pollution due to thermal discharges and chemical and waste disposal; turbidity; water quality standards and pollution control for beneficial uses, emphasis on coastal and nearshore areas.	6
Sediment Type, properties and sources of sediment; sediment transport; deposition and scour; erosion and siltation; beach evolution; prediction and countermeasures; emphasis on estuarine, coastal and nearshore processes.	6

	Suggested Time Allocation per cent
Fixed coastal structures Breakwaters, seawalls, groins, piers, etc.; their functions, stability analysis and design; impact on beach evolution and water exchange.	6
Floating coastal structures Platforms, buoys, floating breakwaters, etc.; their functions, stability and response analysis and design; mooring and anchorages; impacts on the marine environment.	6
Geotechnics Properties of sea floor (soil and rocks); sub-sea slumping, slides and stability; sea floor improvement techniques.	6
Wave and current induced forces Forces due to waves, currents and wind; inertia, drag and lift forces; regular and irregular characteristics; measurement, prediction and evaluation.	6
Physical modelling Theory of similitude law; scale effect; experimental facilities, equipment and measurement techniques; inclusive of exercise in laboratory.	6
Subtotal	62

3. Elective subjects

System design and development	6
Materials	6
Advanced geotechnics: dynamics	6
Data acquisition, analysis and display	6
Marine construction and installation	6
Water quality	6
Marine affairs	6

	Suggested Time Allocation per cent
Numerical modelling (deterministic)	6
Numerical modelling (stochastic)	6
Subtotal	24 *

* A minimum of four electives are required, chosen in consultation with the student's advisor.

4. Project or thesis — 14

5. Additional information

None.

Curriculum total — 100

C. Ocean Instrumentation

1. Objectives

This curriculum is designed to impart knowledge and skills for the development and use of instruments and equipment in relation to the exploration of the marine environment and to technological activities in this environment. The curriculum includes the study of instruments used for precision acoustic ranging, deep ocean contouring, rapid data processing, etc.

2. Core subjects	Suggested Time Allocation per cent
Mathematics Topics from applied mathematics; probability theory statistics.	7.5
Physical oceanography Air-sea interaction, exchange processes for momentum and heat; currents; waves; marine meteorology.	7.5
Data collection systems Particular problems of data collection; probes and sensors, interfaces, signal conditioning and storage; examples relating to current ocean engineering activities.	7.5
Advanced data collection systems Design of systems for deep ocean and estuarine data collection and processing; space-time sampling and multivariate analysis as applied to ocean data estimation; system design.	7.5
Ocean laboratories Measurements, experiments and operation of apparatus in the ocean and in the laboratory; planning short and long-term experiments; checking of data; etc.	7.5
Underwater acoustics Wave equations, energy, pressure and particle velocity; acoustic properties of the sea; elementary sources, refraction, reflection, ray theory, normal modes and scattering; with emphasis on sound propagation in the ocean.	7.5

	Suggested Time Allocation per cent
Advanced underwater acoustics Transducers, radiators and receivers; directivity equivalent circuits; piezoelectricity; magnetrostriction; sonar principles; mathematical and numerical methods with applications to ocean features such as surface ducts, shadow zones, etc.	7.5
Engineering ocean mechanics Applied concepts of ocean flow processes; waves due to gravity, wind and layered media; large and small scale turbulence; prediction of flow instability; wave forces on structures.	7.5
Marine materials Strength properties of metal materials, concrete and plastics; ductile, brittle and fatigue behaviour; fracture mechanics; effects of the environment on material properties; material selection for various applications.	7.5
Seminar Seminar discussions, including presentation of papers based on research or literature survey.	2.5
Subtotal	70

3. Elective subjects

Management	7.5
Economics	7.5
Law	7.5
Man-in-the-sea	7.5
Operations research	7.5
Structures	7.5
Geotechnics	7.5

	Suggested Time Allocation per cent
Biology	7.5
Oceanography	7.5
Subtotal	15 *

* A minimum of two electives are required, chosen in consultation with the student's advisor.

4. Project or thesis — 15

5. Additional information

Shipboard training and other relevant practical experience in the use of instruments is highly desirable.

Curriculum total 100

D. Fisheries Engineering

1. Objectives

The curriculum is intended to educate a student who will be able: (1) to undertake measurement research on fishing gear in such a way that the underlying principles of its mode of operation become established and lead to better designs; (2) to take part in the development of hydroacoustic and other systems that will improve estimations of the magnitude of fish populations and will allow a better measurement of fish behaviour; (3) to play an active role in fisheries research, together with his or her colleagues in the marine sciences; and (4) to be broadly enough trained so that he or she can have flexibility in future employment.

Because only a few countries have fisheries engineering taught to a Bachelor of Science degree level, a short bridging course would be of benefit to students who already have a Bachelor of Science degree in a traditional engineering subject. This course should emphasize construction, design and materials of fishing gear. The curriculum listed here specializes rather heavily in instrumentation, as perhaps the most appropriate specialization, but it is not necessarily the only one.

2. Core subjects

	Suggested Time Allocation per cent
Hydrodynamics of floating and submerged bodies Hydrodynamic principles associated with floating and submerged bodies; resistance, propulsion, static and dynamic stability, problems of manoeuvring, control and motion in waves.	8
Engineering ocean mechanics Applied concepts of ocean flow processes, waves due to gravity, wind and layered media; large and small scale turbulence; prediction of flow instability.	8
Applied mathematics and statistics Conformal transformations; mathematics appropriate to hydroacoustics; numerical methods; statistics appropriate to engineering data and to animal populations.	8

	Suggested Time Allocation per cent
Underwater acoustics Wave equations, energy, pressure and particle velocity, acoustic properties of the sea; elementary sources, refraction, reflection, ray theory, normal modes and scattering with emphasis on sound propagation in the ocean.	8
Navigational aids Hyperbolic systems, satellite systems, underwater systems; automatic track plotting.	8
Computer application and interfacing Description of the underwater acoustic environment; methods of measuring underwater acoustic signals; data analysis of passive and active signals; application of underwater acoustics to a fisheries survey.	8
Biological oceanography and fisheries biology Ocean food resources; food chains; fish behaviour; life cycles and migrations; marine animal locomotion; population dynamics.	8
Instrument sensing elements and underwater telecommunications Practical problems of data collection; probes and sensors; interfaces; signal conditioning and storage; multiplexing; emphasis on examples found among current research areas within fisheries engineering.	8
Seminar Seminar discussions, including presentation of papers based on research or literature survey.	4
Subtotal	68

3. Elective subjects

Management	8
Economics	8
Man-in-the-sea	8

	Suggested Time Allocation per cent
Operations research	8
Other appropriate topics	8
Subtotal	16 *

* A minimum of two electives are required, chosen in consultation with the student's advisor.

4. Project or thesis — 16

5. Additional information

None

Curriculum total 100

TEACHING RESOURCES AND FACILITIES

Introduction

When considering the feasibility of initiating an ocean engineering academic programme, it is imperative that the total range of necessary commitments be assessed. Postgraduate engineering education generally is relatively expensive. Starting a new ocean engineering postgraduate educational programme is particularly expensive in terms of manpower and facilities. Human resources and some physical facilities that ought to be available are discussed briefly in the following sections, together with additional material on teaching aids.

Human Resources

It is expected that all students entering the ocean engineering programme will have had appropriate instruction in the following basic subjects:

- Mathematics (including probability and statistics)
- Computing
- Natural sciences
- Basic engineering
- Economics

together with general introductory lectures on 'engineering and society'. It is therefore also expected that the necessary academic faculty or staff will be available to provide these lectures.

Each year of the ocean engineering programme will occupy about 30 weeks of formal study, representing about 450 hours of lecturing time and a similar amount of programmed study, as previously discussed. This basic lecturing commitment alone will require the services of two or three full-time academic faculty (or the equivalent in part-time faculty). It is suggested that a group of four or five core faculty should initially be appointed since it is highly desirable that the programme should contain electives, and since the lecturing faculty should have the opportunity for research, for interaction with industry and possibly for study abroad. Whether these persons are recruited specially and exclusively for ocean engineering, or are obtained through the services of other departments, will depend on local circumstances. However, it is essential that one member of the academic faculty with the appropriate competence and seniority has the full-time responsibility to lead and manage the ocean engineering programme.

Ocean engineering, being a multi-disciplinary subject, requires the services of various specialists. It is recommended that faculty members with certain speciality areas of expertise should be available from among the full-time faculty. They may either be drawn from the established engineering departments (e.g. civil, mechanical, electrical, naval architecture, etc.), or may be appointed to form a separate ocean engineering group or department. Each such faculty member should have expertise in one or more of the major disciplines identified in the matrix previously presented (Fig. 2).

There are, of course, many other aspects of ocean engineering that may appropriately be included in an ocean engineering curriculum. However, the relevant specialists may not be available on campus, or the topic may not justify recruiting a full-time specialist. For these subjects, it may often be possible to invite special lecturers by visiting staff, consultants or representatives from outside the university, or even outside of the country.

The permanent academic faculty should have a high level of academic proficiency. This will be represented by a doctor's degree or the equivalent in many countries. In such a rapidly changing field as ocean engineering, it is desirable that a balance be maintained among teaching, research and interaction with industry. Therefore, the academic faculty should be protected from too heavy of a teaching load. Besides faculty for teaching and supervision, research associates, having comparable academic qualifications to the faculty, could provide part-time assistance in connection with theoretical and experimental exercises and project work.

Ocean engineering programmes also require (1) technicians with a particular competence for performing laboratory work, handling computers, etc., and (2) other normal support, such as secretarial assistance. With an ocean engineering programme utilizing laboratory facilities of the kind described subsequently, the minimum number of the technical staff would be similar in number to the academic faculty. Additional technicians or secretaries would, undoubtedly, be cost effective to a programme.

Physical Facilities

The recommended minimum physical facilities that ought to be available for the initiation of an ocean engineering programme or department in an educational institution will depend on many factors. It is presumed that an ocean engineering department or programme would only be considered by an institution that already has established conventional engineering departments suitably equipped with appropriate facilities, including machine and instrument shops and a design or drafting room - possibly including computer drafting. There is no order of priority in the following sections.

A. Vessel

Some universities have found it advantageous to operate a small research vessel that would have the following typical characteristics. It should be capable of carrying up to 10 or 12 students and two or three staff, perhaps 10 or 20 km offshore for day trips. The vessel should preferably have sufficient permanent staff to maintain, protect, and improve the vessel for a growing number of teaching experiments. Appropriate and secure dock space and storage facilities must be available. Due regard must be given to ensuring adequate safety of students on board the vessel. The vessel should be supplied with adequate navigation and communication equipment appropriate to the region in which it will operate. Since the purpose of the vessel is to aid in teaching ocean engineering students, sufficient instrumentation and equipment should be available for temporary or permanent installation aboard the vessel to expose the students to up-to-date environmental measuring sensors. These should include current meters, salinometers, tensiometers, accelerometers, dissolved oxygen sensors, temperature gages, under-water camera systems, etc. The vessel's temporary or permanent operational equipment should include an echo-sounder, radar, two-way radio, Decca or Loran receivers if appropriate, seismic profiling equipment, sonar ranging equipment (e.g. for fishing-gear measurement), as well as strip-chart and magnetic tape data recorders.

Ocean engineering programmes may find access to suitable vessels by means of leasing or borrowing arrangements with neighbouring institutions or countries, if they cannot otherwise acquire a new vessel. Part-time or long-term contracting arrangements might be made with a local fisherman or other vessel operator for a vessel meeting minimum requirements; such a vessel might require the temporary installation of additional necessary equipment. While a leasing arrangement may be used as a temporary expedient, in some cases, it may be more cost-effective to purchase an older boat that may be modified over a period of time; possibly ocean engineering students could perform much of the work as part of their practical training? It might also be possible to obtain a vessel as a donation from the government, a foundation, a corporation, private individual or international aid.

B. Demonstration Wave Tank

For educational institutions developing ocean engineering programmes, an important facility is a demonstration wave tank. A minimum tank would be perhaps 1 meter wide, 1 meter deep, and 20 meters in length. The wave maker should at least be capable of generating regular waves in the tank, and a suitable beach termination should be effective in reducing wave reflections to prevent standing wave set-ups.

C. Library

The technical literature in the numerous ocean engineering fields is voluminous. This consists of books, conference proceedings, journals, technical reports, etc. It will be an expensive effort creating a suitable library to assist the teaching and research programmes of the faculty and staff and to provide adequate reference materials for students to supplement the lectures, if the engineering or main university library has not already started to acquire a collection.

Specialists in ocean engineering already will be conversant with the literature in their respective fields. As an aid to others, Annex IV has been created to assist in identifying the literature.

D. Computers

Computers are employed in ocean engineering for analysis and design and for the collection, storage, processing and retrieval of data. Students will certainly use computers and probably plotters as working tools in their professional practice. They should therefore become well familiar with these devices during their studies. Furthermore, working out design exercises as part of the study programme would not be feasible or would take too much time without the use of a computer.

Almost all students entering advanced courses in engineering can develop simple computer programmes. Students who do not have this ability should be exposed to a concentrated course in computer programming at the beginning of their studies.

There is a rapid evolution with regard to computers. High-powered small computers are now on the market. Their cost is only a fraction of that of previous computers of comparable capacity. More and more students will be able to acquire a personal computer, with which many computations needed for ocean engineering can be made.

Each institution engaged in ocean engineering should have a properly documented programme library. In principle, any programme written by a student or a staff member will be stored in this library. To make this procedure effective, programmes should be written on standard forms. Universities can either create these forms or purchase them from appropriate software sources.

A microcomputer laboratory also must be provided for the use of ocean engineering students in gaining both hardware and programming experience. This might be a shared facility with another department if appropriate, but ocean engineering students must have unlimited access to the laboratory. The subject of computer or numerical modelling of complex marine structures, fish net behaviour, estuarine and coastal ocean circulation patterns, etc., will make heavy demands on the use of this laboratory.

Teaching Aids

The technical literature in the various fields of ocean engineering is widely scattered. Few textbooks exist that are suitable for specific courses or subjects. It will be necessary for many teachers to prepare their lectures from papers that have been published in technical journals. Consequently, audio-visual equipment and materials, as well as classroom demonstration models, will be more extensively used than in traditional engineering courses or subjects. Also, outline lecture notes can be reproduced for the students to good advantage. Each department in which ocean engineering subjects are taught should have available for the use of teachers, the following types of audio-visual aids: motion picture projectors and overhead or viewgraph machines for the projection of page-size transparancies. The latter can be photocopied for student use.

It is further suggested that each department or teaching unit begin the compilation of audio-visual materials. A number of useful motion picture films are available for rent or purchase. Video recording equipment has also been found useful in education work. Visiting professors generally have educational materials that often can be duplicated or perhaps donated.

Although somewhat out of date (1975), the Unesco Intergovernmental Oceanographic Commission has published a booklet titled, 'Annoted Bibliography of Textbooks and Reference Materials in Marine Science', which contains a chapter on ocean engineering and technology. Additional, and more up-to-date, references sources are given in Annex IV.

ANNEX I

List of Workshop Participants

Prof. J. B. CALDWELL
Department of Naval Architecture and Shipbuilding
The University of Newcastle Upon Tyne
Armstrong Building
Queen Victoria Road
Newcastle Upon Tyne NE1 7RU
UNITED KINGDOM.

Mr. W. DICKSON (Workshop Rapporteur)
Bath Lodge
6 Bath Street
Stonehaven AB32 DE
Scotland
UNITED KINGDOM.

and

Fiskeri Teknologisk Forsknings Institut
C. Sundsgate 57
Postboks 1964
5001 Nordness, Bergen
NORWAY.

Prof. Keuck Chun KIM
Professor and Chairman
Department of Naval Architecture
College of Engineering
Seoul National University
San 56-1, Shinrim-Dong, Kwanak-Ku
Seoul 151
REPUBLIC OF KOREA.

Prof. Dr.-Ing. K. KOKKINOWRACHOS
Rheinisch-Westfälische Technische
Hochschule Aachen
Templergraben 55
5100 Aachen
FEDERAL REPUBLIC OF GERMANY.

Prof. Ascensio C. LARA
(Vice-President of ECOR)
Centro de Ingeniera Oceanica
Viamonte 1634, Piso 1 (C.I.O.)
1055 Buenos Aires
ARGENTINA.

Prof. Wen-Fa LU
Professor and Head
Offshore Civil Engineering Programme
Department of Hydraulic Engineering
Dalian Institute of Technology
Dalian, 116024
CHINA.

Prof. O. MAMAYEV
Chair of Oceanography
Geographical Faculty
University of Moscow
Moscow - 117234
UNION OF SOVIET SOCIALIST REPUBLIC.

Prof. Foster H. MIDDLETON
Chairman and Professor
Department of Ocean Engineering
University of Rhode Island
Kingston, Rhode Island 02881
UNITED STATES OF AMERICA.

Prof. Torgeir MOAN
Department of Marine Technology
Norges Tekniske Høgskole
7034 TRONDHEIM - NTH
NORWAY.

Prof. L. J. MOSTERTMAN
Director
International Institute for Hydraulic
and Environmental Engineering
Oude Delft 95
P. O. 3015
2601 Delft
THE NETHERLANDS.

Dr.-Ing. V. S. RAJU (Workshop Vice-Chairman)
Professor, Geotechnical Engineering
Ocean Engineering Centre
Indian Institute of Technology
Madras 600 036
INDIA.

Dr. Adrian F. RICHARDS (Workshop Chairman & Unesco Consultant)
(ECOR Representative to IOC/TEMA)
Senior Consultant
Fugro B. V.
P. O. Box 63
2260 AB Leidschendam
THE NETHERLANDS.

Dr. Akira WATANABE
Associate Professor
Coastal Engineering Laboratory
Department of Civil Engineering
Faculty of Engineering
University of Tokyo
Bunkyo-Ku, Tokyo
JAPAN.

Prof. Robert L. WIEGEL
Professor of Civil Engineering
Department of Civil Engineering
412 O'Brien Hall
University of California
Berkeley, California 94720
UNITED STATES OF AMERICA.

Unesco Secretariat:

Dr. Dale C. KRAUSE
Director
Division of Marine Sciences

Dr. Dirk G. TROOST (Workshop Secretary)
Programme Specialist
Division of Marine Sciences

Dr. Mazhar HAQ
Assistant Secretary
Intergovernmental Oceanographic Commission

Dr. Kazu KITAZAWA
Assistant Secretary
Intergovernmental Oceanographic Commission.

ANNEX II

Programme Accreditation and Professional Licensing

It is usually desirable for undergraduate academic engineering programmes to be accredited in order to fulfill the requirements of professional licensing boards. Similarily it is sometimes desirable for postgraduate programmes to be accredited. This is done by a formal review of curricula, faculty, course content, written material, examinations, facilities and equipment on a regular basis (about every five years) by a visiting team of practicing engineers from industry and government agencies and by faculty from other universities.

As a part of this procedure it is recognized that curricula and course content must be modified on a regular basis to keep them current. This task requires the continual interaction of faculty members and practicing engineers.

ANNEX III

Publications Useful for the Design of Curricula

I. Published by or available from Unesco, Paris

Brancher, D., ed. 1980. The environment in engineering education. Studies in engineering education 9. Unesco, Paris. 111p.

Caldwell, J. B. 1982. Teaching marine technology in Europe. A report on a WEGEMT Colloquium to the Unesco workshop on ocean engineering curricula. 11+xxiip. (unpublished).

Grayson, L. P. 1977. The design of engineering curricula. Studies in engineering education 5. Unesco, Paris. 131p.

Richards, A. F., and E. A. Richards. Global survey and analysis of postgraduate university curricula in ocean engineering. Unesco reports in marine science 26. Unesco, Paris. (in print).

Unesco. 1974. Marine science teaching at the university level. Report of the Unesco Workshop on University Curricula. Unesco technical papers in marine science 19. Unesco, Paris. 27p+xip.

Unesco. 1979. Syllabus for training marine technicians. Report of an IOC/Unesco workshop held in Miami, Florida, 1978. Unesco reports in marine science 4. Unesco, Paris. 50p.

Unesco. 1979. Marine science syllabus for secondary schools. Report of an IOC workshop held at United World College of the Atlantic, United Kingdom, 1978. Unesco reports in marine science 5. Unesco, Paris. 45p.

Unesco, 1981. Fishery science teaching at the university level. Report of a Unesco/FAO workshop on university curricula in fishery science. Unesco reports in marine science 15. Unesco, Paris. 75p.

II. Published by other organizations

Anderson, K. E. 1981. Directory of academic marine programmes in California. Institute of Marine Resources, California Sea Grant College Programme, University of California, La Jolla, California. 248p.

Garner, A., and M. Stone. 1982. Marine education in Britain, a survey. In: E. M. Borgese and N. Ginsburg, eds. Ocean Yearbook 3. University of Chicago Press, Chicago. 672p.

Gillie, A. C., and A. L. Pratt. 1971. Marine Technology Programs: where we are and where we're going. American Association of Junior Colleges, Washington, D. C. 55p.

Marine affairs: register of courses and training programmes. 1976. United Nations Department of Economic and Social Affairs, Doc. ST/ESA/54, New York. 157p.

University curricula in the marine sciences and related fields: academic years 1979-1980, 1980-1981. Marine Technology Society, Washington, D. C. 248p.

ANNEX IV

Bibliographies and Selected Publications *

I. Basic references

(a) Annotated bibliography of textbooks and reference materials in marine sciences. 1975 Intergovernmental Oceanographic Commission, Unesco, Paris. 109p.

(b) Myers, A., ed. 1981. Current bibliography of offshore technology and offshore literature classification. A.S.R. Marketing, Berkhamsted, Hertshire, England. 110p.

II. Books

American Petroleum Institute. Recommended practice for planning, designing, and constructing fixed offshore platforms, RP2A (latest annual edition). American Petroleum Institute Pubns., Washington, D.C.

Bhatt, J. J. 1978. Oceanography: exploring the planet ocean. Van Nostrand Reinhold, New York. 102p.

Bhattacharyya, R. 1978. Dynamics of marine vehicles John Wiley, New York. 508p.

Brebbia, C. A., and S. Walker. 1979. Dynamic analysis of offshore structures. Newnes-Butterworths, Woburn, U.S.A. 336p.

Bruun, P. 1981. Port Engineering (3rd edition). Gulf Publishing, Houston, Texas. 787p.

Bruun, P. and F. Gerritsen. 1955. Stability of coastal inlets. North-Holland Publishing, Amsterdam. 123p.

* Contributed by the U.S.A. National Research Council, Marine Board, and other sources. Books listed in I (a) are not included. This list only represents book titles that were readily available when this report was edited. The list is incomplete. The I (b) reference also presents a list of ocean engineering conferences and journals.

Bureau of Ports and Harbours. 1980. Technical standards for port and harbour facilities in Japan. Ministry of Transport, Overseas Coastal Area Development Institute of Japan. 317p.

Coastal Engineering Research Centre. 1975. Shore protection manual. U.S. Army Corps of Engineers, Washington, D. C. 3 vols.

Cooper, H. R. 1975. Practical dredging and other allied subjects (2nd edition). Brown, Son and Ferguson, Glasgow. 450p.

Count, B. M., ed. 1980. Power from sea waves. Academic Press, New York. 449p.

Davis, R. A. Jr., ed. 1978. Coastal sedimentary environments. Springer-Verlag, New York. 420p.

Defant, A. 1961. Physical oceanography. Pergamon Press, Elmsford, New York. 2 vols.

Dronkers, J. J. 1964. Tidal computations in rivers and coastal waves. North-Holland Publishing, Amsterdam. 518p.

Flipse, J. E., ed. 1975. Deep ocean mining. Ocean Engineering Developments 8. American Society of Mechanical Engineers, New York.

George, P. and D. Wood. 1976. Offshore soil mechanics. Lloyds Register of Shipping, London.

Graff, W. J. 1981. Introduction to offshore structures: design, fabrication and installation. Gulf Publishing, Houston, Texas. 375p.

Griffin, O. M., ed. 1978. Ocean thermal energy conversion. Ocean Engineering Developments 5. American Society of Mechanical Engineers. New York.

Griffin, O. M. and J. G. Giannotti, eds. 1980. Ocean engineering for OTEC. Ocean Engineering Developments 9. American Society of Mechanical Engineers, New York.

Halis, J. and A. Carr, eds. 1975. Nearshore sediment dynamics and sedimentation. John Wiley, London. 316p.

Horikawa, K. 1978. Coastal engineering: an introduction to ocean engineering (English edition). University of Tokyo Press, Tokyo. 402p.

Ippen, A. T. 1966. Estuary and coastline hydrodynamics. McGraw Hill, New York. 744p.

Johnson, D. W. 1949. Shore processes and shoreline development. John Wiley, New York. 584p.

King, C. A. M. 1972. Beaches and coast (2nd edition). Edward Arnold, London. 570p.

Kinsman, B. 1976. Wind waves. Prentice-Hall, Englewood Cliffs, New Jersey. 429p.

Komar, P. D. 1976. Beach processes and sedimentation. Prentice-Hall, Englewood Cliffs, New Jersey. 429p.

Lambe, T. W. and R. V. Whitman. 1979. Soil mechanics, SI version. John Wiley, New York. 570p.

LaQue F. L. 1975. Marine corrosion: causes & prevention. John Wiley, New York. 332p.

LeMehanté, B. 1976. An introduction to hydrodynamics and water waves. Springer-Verlag, New York. 512p.

Lighthill, J. 1978. Waves in fluids. Cambridge University Press, Cambridge. 504p.

Malhotra, A. K. An introduction to ocean science and technology. National Book Trust, New Delhi.

McCormick, M. E. 1978. Anchoring systems. Pergamon Press, Oxford. 170p.

McCormick, M. E. 1981. Ocean wave energy conversion, John Wiley, New York. 260p.

Meyer, R. E. and R. E. Meyer. eds. 1972. Waves on beaches and resulting sediment transport. Academic Press, New York. 462p.

Minikin, R. R. 1963. Winds, waves, and maritime structures (2nd edition). Charles Griffin, London. 294p.

Owens, W. L., ed. 1980. Heat transfer in OTEC systems. HTD 12. American Society of Mechanical Engineers, New York.

Peck, R. B., W. E. Hanson, and T. H. Thornburn. 1974. Foundation engineering (2nd edition). John Wiley, New York. 540p.

Ross, D. A. 1980. Opportunities and uses of the ocean. Springer-Verlag, New York. 320p.

Sarpkaya, T. and M. Isaacson. 1981. Mechanics of wave forces on offshore structures. Van Nostrand, London. 651p.

Shepard, F. P. 1978. Geological oceanography: evolution of coasts, continental margins and the deep-sea floor. Heinemann, London. 228p.

Simeons, C. 1980. Hydropower: the use of water as an alternative source of energy. Pergamon Press, Oxford. 560p.

Silvester, R. 1974. Coastal engineering. Elsevier, Amsterdam. 2 vols.

Sorensen, R. M. 1978. Basic coastal engineering. John Wiley, London. 248p.

Steers, J. A. 1964. Coastline of England and Wales (second edition). Cambridge University Press, Cambridge. 750p.

Steers, J. A. ed. 1971. Introduction to coastline and development. M.I.T. Press. Cambridge, Massachusetts.

Stocker, J. J. 195[illegible]. Water waves. John Wiley - Interscience, New York. 595p.

Svendsen, I.A., and I. G. Johnson. 1976. Hydrodynamics of coastal regions. Den Private Ingeniørford, Technological University of Denmark, Copenhagen. 282p.

Underwater soil sampling, testing, and construction control. 1972. Special technical publication 501. American Society for Testing and Materials, Philadelphia. 240p.

Whitham, G. B. 1974. Linear and nonlinear waves. John Wiley, London. 636p

Wiegel, R. L. 1964. Oceanographical engineering. Prentice-Hall, Englewood Cliffs, New Jersey. 700p.

Zenkovich, V. P. 1967. Processes of coastal development. (translated by D. G. Fry and edited by J. A. Steers). Oliver and Boyd, Edinburg and London. 738p.